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DEVELOPMENT OF A PERSISTENT CHEMICAL AGENT SIMULATION SYSTEM

FINAL REPORT

November 23, 1983

JPL Contract No. 956631

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ABSTRACT

Tracer Technologies has developed a Persistent Chemical Agent Simulation System (PCASS) to simulate, for force-on-force training exercises, the field environment produced by the presence of persistent chemical agents. In addition to this report, Tracer Technologies has delivered to JPL for their evaluation the following:

(1) Five gallons each of blister and nerve persistent chemical agent simulants.

(2) Decontamination agent simulant to decontaminate chemical agent simulants which have been sprayed on surfaces.

(3) Detection papers which will indicate appropriate color change to the simulants.

(4) A device for a 60 day loan period to detect the presence of perfluorocarbon tracer material in the chemical agent simulants.

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1.0 INTRODUCTION

The U.S. Army has defined a requirement for a simulant material to aid in training combat force response to an attack with persistent chemical agents. Such a simulant system must satisfy several requirements to be of value as a training aid. Specifically it must provide for realistic training which will generate competency in at least the following areas:

- Detection of the persistent agent presence
- Proper use of protective equipment and procedures
- Determination of the extent of contamination
- Decontamination of equipment and personel.

A suitable simulant system for persistent chemical agent (PCASS) must behave in a manner similiar to a threat agent with respect to its physical behavior and decontamination procedure. It should be detectable by methods and materials which would be employed in an actual scenario or by training methods and materials closely resembling those actual methods. Further, chemical simulants must pose no health threat to trainees, instructors, or by-standers and must not become a source of environmental pollution.

The Jet Propulsion Laboratory has defined functional needs in seven specific areas with characteristics of the PCASS defined as either essential or preferred. These requirements define the idealized PCASS. Tracer Technologies has developed a PCASS which will satisfy the vast majority of these essential requirements. In some cases, the requirements were such that changes were necessary and were discussed with the JPL technical manager. This report will provide the results of the Tracer Technologies PCASS development and the test results which indicate the satisfaction of the contractual requirements. Technical discussions of proposed changes in the requirements and variations in the formulation of the PCASS which will aid the Army in achieving their overall objectives are also included.

2.0 TECHNICAL DISCUSSION

The technical requirements for the persistent chemical agent simulation system (PCASS) are shown as Exhibit 1 of JPL Contract Number 956631 and are included in Appendix 1 of this report. Discussion of each point included in this section refers to the functional requirements by the appropriate section and paragraph number of this Exhibit.

2.1 FORMULATION OF THE PCASS

An in-depth discussion of the formulation of the PCASS follows. In addition to the formulation ingredients, and procedures, an explanation of the interaction of the various components is presented.

2.1.1 SYSTEM RATIONAL AND BASIS

The development of the Tracer Technologies PCASS was approached from the desire to provide an aqueous based system of components which would allow formulation flexibility, ease of field use, and realize economy of use and storage. To this end, various materials widely used in the prepared food and cosmetic industries were investigated as candidates for thickeners, sequestrants, corrosion inhibitors, and pH modifiers. This approach was judged as the most promising in keeping with the safety requirements set forth in the contract.

Common to both the blister agent simulant and the nerve agent simulant are the thickeners used. Both sodium alginate and polyoxyethylene (Union Carbide POLYOX) are used in the two systems although their relative amounts differ. These thickeners are widely used in the food and cosmetic industry.

2.1.2 BLISTER AGENT SIMULANT

The blister agent simulant must posess viscosity characteristics similar to a 30W motor oil, a yellow color, and a garlic-like odor.

To obtain the "feel" of motor oil, a slightly thickend aqueous solution was required. This solution must also provide a lubricant "feel" of slickness. Sodium alginate was used to provide the required viscosity and a small amount of polyoxyethylene was added to provide "slickness". A lubricant "feel" was obtained by adjusting the amount of polyoxyethylene.

To provide a yellow color, 0.2 ml/1 FDC Yellow was added to the blister simulant. The amount of coloring agent was arbitrarily chosen and its final concentration may be adjusted, with ease, to suit those who have actually seen real agent.

Aqueous extract of garlic was chosen as the odorant. While other odorants, such as mercaptan compounds, could probably be considered, the solubility and acceptability of a food additive dictated the choice of garlic extract.

The formulation of the delivered blister agent simulant is:

PART A (Odorant, colorant, pH adjust)

2 % w/v	Citric Acid Monohydrate
0.2ml/l	FDC Yellow Food Coloring
5 ml/l	Aqueous Garlic Extract

PART B (Thickeners, humectant/sequestrant)

0.2% w/v	Polyoxyethylene
0.6% w/v	Sodium Alginate
10% v/v	Polyethylene Glycol 200

Polyethylene Glycol 200 (PEG 200) is utilized as both a humectant and as a sequestrant to aid in solution of the thickening agents. Both sodium alginate and polyoxyethylene flocculate when added directly to water. This results in large masses of the thickening material surrounded by a slowly dissolving gelatinous solid-liquid interface. To allow solution to be effected with minimal agitation or stirring, the thickening materials are suspended in a medium in which they are not soluble but which is soluble in water. When this suspension is dispersed in water, solution of individual particles of thickener is favored.

To effect solution of the components, the solids are dissolved in approximately one-half the final volume of water. The suspension of thickener in sequestrant is then shaken to resuspend the solids and added quickly to the water and shaken vigorously for one minute. The remaining water is added, the solution shaken and allowed to stand for about 30 minutes. After this period, it is shaken again and is ready for use.

Citric acid is utilized as an acidifier to adjust the pH of the simulant to pH 2. This allows determination of its presence by the detection papers which react to pH changes at pH 2 in the acid range. Citric acid is widely used as an acidifier in the beverage industry and the resultant pH of the blister agent simulant is similar to many carbonated citrus-flavored sodas.

2.1.3 NERVE AGENT SIMULANT

A thickened nerve agent simulant is required to have the viscoelastic characteristics of tackiness and stringiness similar to that of honey. To effect this consistency, sodium alginate and polyoxyethylene were again used. To obtain the necessary pH for indication on the detection papers, sodium carbonate monohydrate was used. The nerve agent simulant also contains a corrosion inhibitor (FERNOX, Newage Industries) which, due to its alkalinity, could not be included in the blister agent simulant as its effectiveness would be neutralized by

the citric acid which provides the color change on detection papers.

The formulation of the nerve agent simulant is:

PART A (pH ADJUST, CORROSION INHIBITOR)
0.5% w/v Sodium Carbonate Monohydrate
0.1% w/v FERNOX (Newage Industries)

PART B (THICKENERS, HUMECTANT/SEQUESTRANT)
0.5% w/v Sodium Alginate
0.5% w/v Polyoxyethylene
5% V/V Polyethylene Glycol 300

An increased amount of polyoxyethylene in the nerve agent simulant provides a higher degree of viscosity and elasticity. The agent is quite stringy when poured and maintains a "tacky" feel.

Polyethylene glycol 300 was included in the nerve agent as a sequestrant for dispersion of the thickeners and as a humectant. This higher molecular weight glycol was determined necessary after analyzing the drying mechanics of droplets of the simulant. It appears that the polyoxyethylene strongly binds available water during the drying process. This caused premature "drying" of the material as well as loss of indication on the detection papers. PEG 300 was found superior to PEG 200 in maintaining the desired characteristics of the droplets over a longer time period.

The action of the thickener/sequestrant suspension and the mixing mechanics are identical to those for the nerve agent simulant.

2.1.4 DECONTAMINATION SOLUTIONS
The aqueous based PCASS provides several advantages when simulating decontamination procedures and agents. The nerve and blister agent simulants are readily removed with water or isopropyl alcohol. Thus, it is sufficient to add materials to water to give the appearance of actual decontamination agents.

2.1.4.1 DECONTAMINATION AGENT DS2
As discussed above, the agent simulants are readily soluble in water and hence DS2 can be suitably and economically simulated by using water. This being the case, no formulation information is offered and this component was not shipped with the evaluation material.

2.1.4.2 ISOPROPYL ALCOHOL (PERSONAL DECONTAMINATION KIT)
Again, water can be substituted for this decontamination agent. Alternately, isopropyl alcohol could be used at higher cost.

2.1.4.3 SUPERTROPICAL BLEACH

In order to provide a Supertropical Bleach (STB) simulant, it was necessary to devise a system which had the appearance of a slurry but which would allow spraying for 4 hours without settling.

Calcium carbonate was initally investigated and provided a good visual appearance but posessed a rapid particulate settling rate. It was decided that a milky color and some particulate would be a reasonable compromise. To this end, a combination of calcium carbonate (for particulate) and powdered milk solids (for color) was chosen. The formulation is as follows:

5g/1	Calcium Carbonate
10g/1	Powdered Milk

Due to the presence of powdered milk, it is advisable to mix this simulant only when needed and to discard any unused portions in order to prevent souring.

2.1.5 DETECTION PAPERS

The ability to detect the agent simulants by color change on M8 and M9 detection papers or their training equivalents was investigated. The use of M8/M9 papers was abandoned early on as it was found impossible to evoke a color change with materials compatible with an aqueous based system and in keeping with the safety requirements of the contract.

Readily available titration end-point indicators were investigated with respect to their sensitivity and compatibility with other indicators in solution. Various papers were then investigated as candidates for use as a vehicle for the indicators.

The desired color response of M8 analog paper is a yellow change for nerve agent simulant and a red change for blister simulant. The M9 analog should show a red color change for either material.

To this end, candidate indicators were chosen which, in combination, would be an orange or brown color and would give a clear color change at pH 2 and pH 11. The actual indicators and their interaction is presented with each formulation.

The pH of various types of paper varies greatly as a result of chemical treatment in the manufacturing process and can effect moderate color change in some dye solutions. Standard laboratory blotting (bibulous) paper was ultimately chosen for use due to near neutral pH and its absorbtive properties.

Samples of the detection papers supplied for evaluation were subjected to direct sunlight for a total of 48 hours. While some fading of color occurred, the papers still provided a clear reaction to the agent simulants.

2.1.5.1 M8 SUBSITUTE DETECTION PAPER
The formulation for the M8 training substitute is:

500mg	Methyl Red
100mg	Neutral Red

Dissolve in 1 liter methanol and store in amber glass container.

Methyl Red is yellow at neutrality and changes to red below a pH of about 3. Neutral Red is red at neutrality and changes to yellow above approximately pH 10. In combination, the resultant solution is orange.

Bibulous paper was saturated in the solution and allowed to air dry thouroughly. The resultant paper is an orange-brown which exhibits a marked red color change at pH 2 and a vivid yellow change at pH 11.

2.1.5.2 M9 SUBSTITUTE DETECTION PAPER
The formulation of M9 substitute follows:

500mg	Methyl Red
500mg	Cresol Red

Dissolve in 1 liter methanol and store in amber glass container.

Methyl red is yellow at neutrality and chages to red under acidic conditions. Cresol red is also yellow at neutrality but chages to red under alkaline conditions. The resultant combination is yellow-orange at neutrality and changes to red at pH 2 and pH 11.

The M9 subsitute paper is prepared in the same manner as the M8. The resultant paper is light brown in color.

2.1.6 PERFLUOROCARBON TRACER EMULSION
Perfluorocarbons are insouluble in water and, therefore, must be either emulsified or added with a co-solvent when their dispersion in an aqueous medium is desired. The emulsion technique was selected for use in the PCASS as it is a nearly equivalent emulsion which is being used as a blood substitute.

For the small quantities of perfluorocarbon emulsion required for this effort, a laboratory hand homogenizer was used for the emulsification process. Pluronic F-68 (BASF-Wyandotte) was used as the surfactant to aid in forming a stable micro-emulsion. The required amount of

perfluoro(methyl)cyclohexane was added to a 4% (w/v) solution of Pluronic F-68. This mixture was shaken vigorously and transferred to the homogenizer reservoir. The mixture was passed through the homogenizer three times with increased shear on each pass. Emulsions resulting from this process have been demonstrated as stable with respect to temperature and storage. While some separation seems to occur with time, shaking the container of emulsion restores its homogeniety.

2.2 SATISFACTION OF REQUIREMENTS

The detailed requirements for the PCASS are listed in Appendix 1. An abbreviated statement of the acceptance criteria is included at the beginning of each discussion point for ease of reading this report.

2.2.1 TRAINING SIMULATION

2.2.1.1 Field Use

B.1.a.(1) Sprayable with atomizer at 40 psi. Decontamination agent sprayable with hand pump sprayer. Detection instrument issues go/no-go indication.

The blister agent, having the consistency of light oil, is easily sprayed with an atomizer or hand pump sprayer. The presence of the perfluorocarbon in the simulant allows the detection of the drops with the Tracer Technologies supplied instrument as long as the droplet is wet enough to continue to hold the perfluorocarbon. Since the perfluorocarbon outgasses from the simulant over a period of time at a rate faster than the droplets are drying, the detection time using the instrument is shorter than the detection time using the simulant papers.

The thickened nerve agent behaves significantly different than the blister simulant or water. Its drying time and characteristics are quite different. It appears to form a thin skin over the droplet and then dry in a period of time roughly half that of the blister agent simulant. Because of the presence of the skin, the perfluorocarbon outgassing occurs at a slower average rate and thus inhibits detection by the Tracer Technologies instrument. However, initial detection by the instrument is good.

The agent simulant may not be atomized as easily as the blister agent due to its high viscosity. Discussions with the JPL technical monitor indicate that this was expected and that the simulant may be diluted in order to satisfy this requirement.

B.1.a.(2) 5mm droplets on aluminum foil less than 2mm after 8 hours.

B.1.a.(3) 5mm droplets on aluminum foil less than 0.5mm after 16 hours.

B.1.a.(4) No color change on detection paper after 16 hours.

The requirements noted are somewhat inappropriate since experiments show that the droplets do not shrink radially but, rather, maintain their original diameter while drying and flattening in the vertical dimension. Thus, the requirement was taken to mean that the droplet would mark the paper at approximately 8 hours and not show any evidence of indication on the papers after 16 hours when exposed to 80°F and 50% relative humidity. We have found that this could be accomplished and, by the introduction of the proper amount of PEG into the solution, we were able to control the drying time over a wide range of conditions.

In our investigations, however, we also realized that the temperature and relative humidity criteria are extremely harsh and that under almost all conditions expected other than certain desert climates, the PCASS would last longer than desired. Our estimate of drying time for conditions one might encounter in Alabama or Washington, for example, show that the PCASS would last from 2 to 8 times as long as at the required test condition (see Appendix 2). This would render the agent simulants unacceptable for rapid re-use of a training area. Some latitude exists in the formulation which allows shortening of the drying time. Our recommendations in this regard are presented in Section 4.0 of this report.

B.1.a.(5) Color change on papers after 8 hour exposure to -7°C/100% RH

After 8 hours of exposure to -7°C at 100% relative humidity, the blister agent simulant has the consistency of a slush and will cause color change on the detector paper substitutes.

2.2.2 CUES FOR TROOPS

B.2.a.(1) Nerve agent simulant clear and stringy.

Indications from the JPL technical monitor and Army representatives indicate that the simulant does meet the appearance requirement noted.

B.2.a.(2) Blister agent simulant has appearance and feel of 30W oil, yellow color, and garlic odor.

Indications from the JPL technical monitor and Army representatives indicate that the simulant does meet the appearance requirement noted.

B.2.a.(3) Blister agent shall have latent casualty indication.

The PCASS developed here does not posess a means for latent indication of spot contamination. It can, when used with the perfluorocarbon tracer provide a means of determining exposure while unmasked by indicating the presence of perfluorocarbon in exhaled air. However, concentration limits required and optimization of the instrument provided for evaluation are beyond the scope of ths contract effort.

2.2.3 Detection by Troops

B.3.a.(1) Give yellow color (nerve) and red (blister) on M8 equivalent paper and red for both on M9 equivalent paper.

Both simulants clearly give the expected reactions with the simulant papers. The color indications match the color indications of the real agents on detection papers extremely well.

2.2.4 DECONTAMINATION

B.4.a.(1) No indication on detection papers 2 minutes after decontamination.

The water soluble simulants are completely removed by pressure spray or scrubbing with the decontamination agent simulants.

B.4.a.(2) No indication on detection papers after hasty decontamination with DS-2 decontamination agent simulant.

Decontamination with DS-2 decontamination agent simulant removes the agent simulant and causes no indication on the detection paper subsititute.

B.4.A.(3) Decontamination with 50% isopropanol gives no indication after 2 min

Decontamination with 50% isopropanol gives no indication on detection paper substitutes if thorough wiping is employed.

B.4.a.(4) Visual appearance of DS-2 decontamination agent.

Water is used as the DS-2 decontamination agent simulant and hence is colorless.

B.4.a.(5) Visual appearance of Supertropical Bleach. Settling time minimal to allow spraying within 4 hours of mixing.

The STB simulant is a milky solution containing particulate matter to give the appearance of a slurry. It is sprayable after 4 hours of standing time.

B.4.a.(6) Thermal decontamination of 2mm drops at $2g/M^2$ with 100°C for 10 seconds.

These criteria are lacking an important variable in the determination of the amenability of the PCASS to thermal decontamination. At the stated temperature, both simulant materials lasted nearly 30 seconds with a linear velocity of the hot air of 5 m/s. It is believed that this requirement is in keeping with the proposed jet-blast decontamination method where considerably higher linear velocities would deform the droplets, increasing their surface area, and increasing forced convective evaporation. In view of the low air flow results and estimates of jet blast characteristics, we believe that this requirement will be met.

2.2.5 TRAINER DETECTION

B.5.a.(1) Detect 2mm drops at a density of $2g/M^2$ within 10 seconds. No detection after application of decontamination agents. No detection after 16 hours.

The detection instrument will give a positive response to the required droplet loading within 5 seconds. It will not respond after application of decontamination agents nor after a period of 16 hours.

B.5.a.(2) The means of trainer detection will be transparent to trainees.

The detection instrument may be made remote indicating to accomplish this requirement.

2.2.6 SAFETY

B.6.a.(1) List toxicology of each ingredient

With the exceptions of polyoxyethylene and FERNOX, all component parts of the nerve and blister agent simulants are to be found among the recognized as safe group of

food and cosmetic additives as found in Title 21 of the Code of Federal Regulations.

The manufacturers of FERNOX (Newage Industries) and POLYOX (Union Carbide) have supplied detailed safety information on these products. Copies of the manufacturers data may be found in Appendix 3.

Both materials appear to be acceptable for use in a non-toxic system. While FERNOX is non-toxic in itself, its ability to scavange oxygen could produce anoxia if ingested in large quantities. It is believed that the amount of FERNOX present in the PCASS is small enough to cause no ill effect.

Sodium Carbonate, sodium alginate, polyethylene glycol, citric acid, garlic extract, and yellow food coloring are among materials generally recognized as safe by the Food and Drug Administration.

The following are the limits on use of these materials as set forth in Title 21:

SODIUM AGINATE: Title 21 Part 184.1011 states that, as a thickener, sodium alginate may be used in an amount "not to exceed current good manufacturing practice."

CITRIC ACID: Title 21 Part 169 states that citric acid bay be used in an amount not to exceed current manufacturing practice but does not quantify the amount except for such foods as pickles.

SODIUM CARBONATE: Title 21 Part 182.1191 states that this substance "is generally recognized as safe when used in accordance with good manufacturing practice."

POLYETHYLENE GLYCOL: Title 21 Part 172.080 states that polyethylene glycol (not to exceed 0.2% ethylene and diethylene glycols) is recognized as safe when "it is used in an amount not greater than that required to produce the intended physical or technical effect."

Aqueous garlic extract and yellow food coloring are assumed safe due to their availability in food markets. Powdered milk is an accepted food substance. Calcium Carbonate is not present in sufficient quantity to be considered harmful.

Perfluorocarbons (tracer material) and their emulsifier are currently being used as blood substitutes and plasma expanders and are pending FDA approval. Their inert nature and presence in low concentration (0.5%) pose no forseeable health hazard.

B.6.a.(2) List environmental acceptability.

No negative comment, sanction, or restriction has been placed on any component of this PCASS by the Environmental Protection Agency based upon telephone conversations with Ms. Kathy Taylor of the Industrial Assistance Group,

B.6.a.(3) Pose no fire hazard in storage or use.

No component of the PCASS poses a threat of fire or explosion in storage or use if handled in accordance with directions for use and stored in original containers until time of mixing.

2.2.7 GENERAL

B.7.a.(1) (a)No rust on mild steel. (b) No corrosion on aluminum foil after 24 hours. (c)No stain on olive drab canvas.

(a) The rust inhibitive properties of the nerve agent simulant meet this requirement. Slight discoloration of the steel is noted with the blister simulant. (b)Neither simulant agent discolors or corrodes aluminum foil. (c) Neither agent causes perminent staining on olive drab canvas.

B.7.a.(2) Agent simulants removable from clothes by normal laundering.

Normal laundering removes the water based agent simulants. There appears to be no staining of the material.

B.7.a.(3) Agent simulants field preparable.

Both agent simulants are preparable in the field with no requirement for heating the material. For small quantities, shaking can be used to effect solution of the component parts. For larger (greater than one gallon) quantities, a method of stirring the materials in an appropriate mixing container is required.

B.7.a.(4) Decontamination agent simulant field preparable.

The entire PCASS may be prepared in the field in varying quantity. Supplied in containers of concentrated additive which are added to water, resulting in ease of operation, economy of use, and reduced storage requirements.

B.7.a.(5) Cost less than $7.00/gallon.

The cost of the Agent simulants is less than $2.50 per gallon without perfluorocarbon tracer. A cost analysis is presented in Appendix 4.

B.7.a.(6) Components field storable and mixable after cyclic exposure to -45°C for 24 hours and +45°C for 24 hours.

All components are believed to meet this requirement. The lowest available sustained temperature available at the time of testing was -18°C. No degradation of components was observed at this temperature. None of the components are believed to be adversely affected by freezing.

B.7.a.(7) Compatible with existing decon equipment (M11 spray device).

All decontamination agent simulants are believed compatible with existing decontamination spray equipment.

2.3 ADDITIONAL TEST RESULTS

2.3.1 EFFECT OF GLYCOL ADDITION

It has been determined that the drying characteristics of the agent simulants can be modified by the appropriate choice of molecular weight and amount of polyethylene glycol added to the mixture.

As an example, blister agent simulant lacking PEG lasted less than 2 hours at 80°F/50% RH. When 30% PEG200 was used, the simulant lasted nearly 24 hours before its ability to produce a color change on detection paper ceased.

2.3.2 DETECTABILITY OF PERFLUOROCARBON TRACERS

The lower limit of sensitivity of the instrument provided to JPL for evaluation of the PCASS is approximately 0.5 parts-per-million (vapor v/v) of the tracer material. The necessarily high concentration of tracer material in the simulant required to produce the required vapor concentration raises the cost of the simulant material significantly when the low sensitivity halocarbon detector is employed. Instrumentation exists which will detect the tracer material at concentrations up to 4 orders of magnitude lower. This instrumentation is currently being re-designed to allow its use in the field and should contribute to lowered cost for the simulant materials when the tracer is used.

Initial test results indicate that, at 0.5% perfluorocarbon content, breath analysis for latent casualty detection is beyond the capability of the

instrument provided for evaluation. Complete testing of the breath analysis technique and the required instrument modification are beyond the scope of this contract. Initial indications are that such a technique is possible.

3.0 CONCLUSIONS

Tracer Technologies has successfully developed an aqueous based PCASS which meets the majority of the essential and desired characteristics set forth by the Jet Propulsion Laboratory. Additionally, a perfluorocarbon tracer material has been successfully introduced into the blister and nerve agent simulants.

The addition of perfluorocarbon tracer to the agent simulants may allow (1) assessment of decontamination efficiency (2) quantitative measurement of the amount of agent simulant remaining in an area as a function of time, and (3) the determination of latent casualties. while full development of the last two characteristics required development which fell beyond the scope of this contract we believe that they show sufficient feasibility to warrant further investigation.

4.0 RECOMMEDATIONS

Three major areas of investigation are apparent as a result of this study. Specifically, the areas are: (1) the miniaturization of an instrument which can provide the required sensitivity necessary for use as a latent casualty indicator, (2) the continued evaluation of the PCASS and instrument for field use, and (3) the development of several formulations of the PCASS for use in varying climatic conditions.

4.1 CONTINUED DEVELOPMENT OF THE PERFLUOROCARBON DETECTOR.

The Tracer Technologies Halocarbon Detector furnished to JPL has a measurement sensitivity of approximately 0.1 to 1.0 parts-per-million. It is not specific for perfluorocarbons and responds well to halocarbons in general. In order to provide a latent casualty indication (i.e. determine from an individual's breath that exposure to the PCASS had occurred), our calculations show that the sensitivity of the instrument must be increased to allow concentration measurements of the order of 100 parts-per-trillion. Laboratory studies indicate this is achieveable. Tracer Technologies, using other types of instrumentation for the determination of sulfur hexafluoride, has made realtime measurements of concentrations to 10 parts-per-trillion on a routine basis. See Appendix 6 for a more detailed discussion of instrumentation requirements.

4.2 MINIATURIZATION AND RUGGEDIZATION OF A DETECTION

4.2 MINIATURIZATION AND RUGGEDIZATION OF A DETECTION INSTRUMENT.

To fully utilize this PCASS in a training program, the detection instrument must be suitably miniaturized and modified to suit a military field environment. Such an instrument is within the current state-of-the-art but should probably not be developed outside the task described in paragraph 4.1.

4.3 MULTIPLE FORMULATIONS OF THE PCASS FOR VARYING ENVIRONMENTS.

As indicated in the report, the PCASS was developed to last approximately 8 hours at a temperature of 80°F and 50% relative humidity. The time requirement was established to provide for rapid re-use of a training area. However, our experiments and calculations (see Appendix 2) indicate that under most conditions, other than desert climates, the PCASS would last significantly longer than desired. The experiments performed under this contract also indicated, however, that modification of the PCASS could be achieved to allow more rapid evaporation times. Tracer Technologies believes that multiple formulations or a system of incremental packaging with a climate versus amounts mixing chart should be developed to allow optimum use of the PCASS under the majority of environmental conditions.

REQUIREMENTS FOR A PERSISTENT CHEMICAL AGENT SIMULATION SYSTEM (PCASS)

A. INTRODUCTION

The U.S. Army requires the availability of a PCASS for simulating, during training, an attack upon its personnel with persistent chemical agents.

There are several classes of antipersonnel toxic chemical agents which might be simulated. One of these classes is the one broadly defined as nerve such as Soman (pinacolyl methyl phosphonofluoridate); another class is known as vesicants (blister) such as mustard gas (bis(2-chloroethyl) sulfide).

To be acceptable as a training simulant system, several general objectives must be realized through its use.

All Army personnel must be able to:

1. Detect the presence of persistent chemical agents.
2. Properly use protective equipments and procedures so that individuals and units can adjust to the chemical agent environment and continue their mission.
3. Reconnoiter ground areas to determine location, extent, and concentration of contamination by persistent chemical agents.
4. Report the findings of their reconnaissance.
5. Recognize during day and night operations the markers or signs placed to define areas of chemical agent contamination, and the procedures to be taken when encountered.
6. Decontaminate equipments, personnel, and specified areas to reduce or eliminate the casualties caused by persistent chemical agents.

All Army commanders must be able to apply correct principles (such as contamination avoidance) to control the operation of their units so as to achieve their mission when persistent agents are encountered.

Army trainers must be able to verify that proper chemical warfare defensive procedures (such as decontamination) were used by the trainees.

Thus, the principal requirements for a training system for simulating a persistent chemical agent attack is the development of:

1. nontoxic materials which, to the human senses, act like persistent chemical agents.
2. nontoxic materials which act like Army decontamination agents to remove or deactivate the simulated persistent chemical agents.
3. a device which can be used by an Army trainer for detecting the presence of the simulated persistent chemical agents.

The current effort being conducted is to define concepts and evaluate in the laboratory at the JPL the technology available for producing a safe PCASS.

One potential approach, but others are expected and will be considered, for providing a PCASS is to have the following:

1. A material that can be deposited on the training field during training exercises which looks to a trainee like a persistent chemical agent.
2. A material in a personal decontamination kit that could be used like the Army M256 or M258 kits for use on the skin or clothing.
3. A material that could be used like the Army DS2 for decontaminating Army weapons or field equipment.
4. A means for detecting, by Army trainers, the presence of the persistent chemical agent simulant which was not removed or decontaminated by the decontaminating agent simulant because of improper use of Army decontamination procedures by trainees.

B.FUNCTIONAL REQUIREMENTS

The requirements cited below are divided into two types - mandatory and desired. In order to receive payment in full, the Contractor shall deliver a PCASS which meets all of the mandatory requirements. The desired requirements are only desired by JPL. They are to be balanced in developing a system of optimum value to JPL.

1. Training Simulation

a. MANDATORY

(1) The PCASS shall be capable of being used in the field or for classroom demonstrations at the US Army Chemical School, Fort McClellan, Alabama, and at US Army posts, camps and stations worldwide.

Note: "Field use" means that a simulant agent is deposited or sprayed so that a trainee can visually locate droplets in the contaminated area when looking for the simulant agent on: the ground or on vegetation covering an area of one square meter to one square kilometer, man-made structures (roads, buildings or bridges), exterior metal, painted metal, fabric or plastic surfaces of small and large Army field equipment, and skin or clothing of Army trainees.

*****

This requirement shall be considered acceptable by JPL when:

(a) The thickened nerve simulant agent and the blister simulant agent can be atomized and sprayed from a 500 milliliter bottle using a 40 pounds force per square inch gage (psi) air supply, and

(b) The decontamination simulants can be sprayed from a household 500 milliliter plant or laundry water spray, and

(c) The trainer detection instrument can detect the presence of the simulant agents before decontamination and the absence of the simulant agents after decontamination.

(2) The PCASS shall be capable of providing toxic chemical agent experience to all active and reserve components conducting combined arms force on force training exercises which can last up to 8 hours.

*****

This requirement shall be considered acceptable by JPL when 5 millimeter diameter drops of each of the simulant chemical agents, deposited on an

aluminum foil surface, are not smaller than 2 millimeters in diameter after 8 hours exposure to the ambient atmosphere at 80° F and 50 percent relative humidity.

(3) The PCASS shall be capable of permitting the reuse of training areas after a period of 16 hours on a noninterference basis.
*****
This requirement shall be considered acceptable by JPL when 5 millimeter diameter drops of each of the simulant chemical agents, deposited on an aluminum foil surface, are not larger than 0.5 millimeters in diameter after 16 hours exposure to an ambient atmosphere at 80 F and 50 percent relative humidity.

(4) The persistent agent simulant shall not be capable of detection by detection papers after 16 hours.

Note: Also see requirement 3.a.(1) and 3.b.(1) below.
*****
This requirement shall be considered acceptable by JPL when 5 millimeter diameter drops of each of the simulant chemical agents, deposited on an aluminum foil surface, do not cause correct color changes in the detector papers after 16 hour exposure to an ambient atmosphere at 80 F and 50 percent relative humidity.

(5) The PCASS shall be useable over a wide temperature range (-7° to +38° C), humidity conditions (desert, 10% relative humidity to tropical, 90% relative humidity) and normal terrain and weather conditions (in the presence of snow but not rain).
*****
This requirement shall be considered acceptable by JPL when 5 millimeter diameter drops of each of the simulant chemical agents, deposited on an aluminum foil surface, will cause color changes in the detector papers after 8 hour exposure to an ambient atmosphere at -7° C and 100 percent relative humidity.

b. DESIRED

(1) The persistent chemical agent simulant should be able to be applied by being disseminated as droplets 1 to 5 millimeters in diameter.

Note: Application techniques would include aircraft or helicopter spray tank, explosive breakup of the persistent agent simulant from a mine or projected plastic container, or on the ground by hand or motorized spray equipment such as used commercially for insecticides.

(2) The presence of the persistent chemical agent simulant should not be visually apparent after 16 hours.

(3) The PCASS should be useable over a temperature range of -40° to +45° C.

2. Cues for Troops

a. MANDATORY

(1) One formulation of the persistent agent simulant shall have the visual appearance and feel of a thickened nerve agent.

Note: The appearance and feel shall be like that of a viscoelastic fluid (stringy, sticky or tacky liquid). On a smooth painted nonabsorptive surface this simulant shall appear visually similar to a 1 to 5 millimeter diameter drop of colorless honey. The droplet shall also be tacky like honey, melted roofing or asphalt tar.

*****

This requirement shall be considered acceptable by JPL when 5 millimeter diameter drop of the simulant chemical agent, deposited on an aluminum foil surface, has the appearance and feel of a honey like viscoelastic fluid (stringy, sticky or tacky liquid).

(2) A second formulation of the persistent agent simulant shall have the visual appearance of a blister agent.

Note: This simulant can be characterized by an oily-like liquid, yellow color and garlic or wild onion odor.

*****

This requirement shall be considered acceptable by JPL when 5 millimeter diameter drop of the simulant chemical agent, deposited on an aluminum foil surface, has the appearance and feel of 30 weight motor oil and smells like garlic, onions, or wild onions.

(3) The persistent chemical agent simulating the blister shall have a latent casualty indication which can be developed, or will automatically develop, to indicate prior blister agent contamination.

3. Detection by Troops

a. MANDATORY

(1) The persistent chemical agent simulant shall be detectable when using either the Army M8 and M9 chemical agent detector papers or surrogate papers (furnished by the Contractor).

Note: "Detectable" is defined as causing the yellow (nerve) or red (blister) color changes used for the US Army ABC-M8 paper and the red color change of the US Army M9 paper or the specified color changes to the surrogate papers when a droplet falls on or a droplet sample is applied to the paper.

*****

This requirement shall be considered acceptable by JPL when 2 millimeter diameter drops of each of the simulant chemical agents, deposited on an aluminum foil surface or when a droplet falls on or a droplet sample is applied to the paper, cause the yellow (nerve) or red (blister) color changes used for the US Army ABC-M8 paper and the red color change (for either simulant) of the US Army M9 paper or surrogate papers (furnished by the Contractor).

b. DESIRED

(1) The persistent chemical agent simulants should be detectable by using training simulant agent detector papers prepared for the PCASS to appear and act like the Army M8 and M9 detector papers.

Note: "Detectable" is defined as causing the yellow (nerve) or red (blister) color changes used for the US Army ABC-M8 paper and the red color change of the US Army M9 paper when a droplet falls on or a droplet sample is applied to the paper.

Note: The training detector paper is not needed if the M8 and M9 papers above can be used.

4. Decontamination by Troops

a. MANDATORY

(1) The simulant decontaminate solution shall deactivate, destroy or remove the persistent chemical agent simulant.
*****
This requirement shall be considered acceptable by JPL when the persistent chemical agent simulants do not provide and indication on the trainer detection instrument 2 minutes after appliacation in accordance with instructions provided with the simulant decontamination agents.

(2) The PCASS shall be suitable for simulating Army hasty or partial chemical agent decontamination procedures.

Note: Hasty or partial decontamination is defined as those decontamination processes (physical removal and chemical reaction with a decontaminating agent to destroy the persistent chemical agent) in less than thirty minutes.

Note: These decontamination processes would presumably be conducted in a forward battle area using personal decontamination kits for skin, clothing, or individual equipment (rifle or weapon), and the 1 quart to 5 gallons of DS2 decontamination solution contained in Army spray equipment for decontamination of individual equipment (rifle or weapon), and small areas (1 to 10 square meters) on large equipment (tank or armored personnel carrier.

(3) For personal skin and clothing decontamination the decontamination simulant shall be able to be prepared so as to appear like isopropanol.
*****
This requirement shall be considered acceptable by JPL when the persistent chemical agent simulants do not provide and indication on the trainer detection instrument 2 minutes after application of 50 percent isopropyl alcohol water solution from the US Army Training Aid, Personal Decontamination Kit, M58A1.

(4) For hasty decontamination, the decontamination simulant be able to be prepared so as to appear like a solution of Army decontaminate DS2.

*****

This requirement shall be considered acceptable by JPL when the DS2 decontamination simulant visually appears like DS2.

(5) For complete decontamination, the decontamination simulant shall be able to be prepared so as to appear like the white slurry of Army supertropical bleach (STB).

*****

This requirement shall be considered acceptable by JPL when the STB slurry decontamination simulant visually appears like a 40 percent by weight slurry of STB, and does not settle such that it can be sprayed within 4 hours.

(6) The PCASS shall be able to use thermal decontamination procedures (100°C for 10 seconds to decontaminate).

Note: This requirement is in consideration of the new US Army Jet Exhaust Decontamination System (JEDS) which uses the thermal heat of jet engine exhaust gases to vaporize and decompose agents; when decontaminating chemicals are added to the exhaust gas stream chemical agent decomposition will occur by solvation and chemical reactions.

Note: The persistent chemical agent simulant should either be able to be vaporized or destroyed by the thermal jet, or destroyed chemically by additives in the jet exhaust. The decontamination simulant will be considered for use as and additive in the JEDS.

*****

This requirement shall be considered acceptable by JPL when the trainer detector instrument does not indicate the presence of the simulant agents from 2 millimeter diameter drops at a concentration of 2 grams per square meter, after exposure of the simulant agent sample to 100°C for 4 seconds.

b. DESIRED

(1) The PCASS should be suitable for simulating Army complete persistent chemical agent decontamination procedures.

Note: "Complete decontamination" is defined as those decontamination processes which would be done in a protected rear battle area to decontaminate personnel so as to be able to remove the protective mask and clothing, individual equipment (rifle or weapon), and large equipment (tank or armored personnel carrier).

Note: These procedures use Army power driven decontamination equipment, water and decontaminating chemicals in large quantities (55 gallon drums of DS2 and tonnage quantities of Supertropical Bleach).

5. Trainer Detection

a. MANDATORY

(1) The PCASS shall be such that a trainer can determine improper decontamination procedures.

*****

This requirement shall be considered acceptable by JPL when:

(a) The trainer instrument can detect 2 millimeter diameter drops of the simulant chemical agents deposited at a concentration of 2 grams per square meter within 10 seconds.

(b) The trainer instrument will not detect the presence of 2 millimeter diameter drops of the simulant chemical agents deposited at a concentration of 2 grams per square meter after application of any of the three decontamination simulants after 30 seconds.

(c) The trainer instrument shall not detect the presence of 2 millimeter diameter drops of the simulant chemical agents deposited at a concentration of 2 grams per square meter after 16 hours of atmospheric exposure when conducting a instrument exposure of 30 seconds.

(2) When conducting chemical warfare training exercises, the trainer detector means for the PCASS shall not be visually evident to trainees unless the trainer elects to do so.

6. Safety

a. MANDATORY

(1) The PCASS shall be nontoxic to personnel; it shall not cause immediate or long-term health problems through contact or inhalation of vapors or fumes.

*****

This requirement shall be considered acceptable by JPL when Environmental Protection Agency (EPA) or Federal Food and Drug Administration (FDA) documentation or equivalent is furnished to JPL which indicates the toxicology of each separate ingredient.

(2) The PCASS shall not damage the environment.

Note: This includes considering the potential detrimental effects of chemicals that would normally be used in farming for chemical fertilizers or considered to be beneficial.

*****

This requirement shall be considered acceptable by JPL when EPA or FDA documentation or equivalent, pro and con, is furnished to JPL which indicates the environmental acceptability of each separate ingredient.

(3) The PCASS materials in dispersed, concentrated or bulk form when placed, stored or mixed together shall not be a fire or other hazard in field use or storage conditions.

b. DESIRED

(1) The PCASS materials in dispersed, concentrated or bulk form should not require protective safety equipment for personnel who work with or store it.

7. General

a. MANDATORY

(1) The PCASS shall not corrode, damage, remove paint or lubricants, or increase first echelon maintenance for: packaging materials, Army vehicles, decontaminating equipments, and other equipment (such as protective mask and hood, wind screens, tentage, or canvas covers).

*****

This requirement shall be considered acceptable when:

(a) The PCASS simulants alone or mixed together do not cause rust to appear on sandblasted mild steel after 24 hour exposure or until droplets dissipate, whichever occurs first, sufficient to discolor white fabric or paper, (it is intended that the PCASS exhibit rust inhibitive characteristics).

(b) The PCASS simulants alone or mixed together do not cause corrosion to appear after 24 hour exposure on aluminium foil.

(c) The PCASS simulants alone or mixed together do not cause staining to appear after 24 hour exposure on olive drab color canvas.

(2) PCASS shall be such that the simulants can be removed from fabrics by normal laundry and cleaning processes.

*****

This requirement shall be considered acceptable by JPL when Army Battle Dress Uniforms contaminated with 5 millimeter drops of simulant agents at a 2 gram per square meter concentration before or after decontamination simulants have been used do not show staining or damage after laundry in warm water without bleach.

(3) The PCASS shall be able to be prepared and loaded in the field during the training exercise to become the simulant for thickened nerve agent and, with a change in formulation or field preparation, the blister agent.

Note: It can be assumed that equipment for mixing and heating up to 180°F in 50 gallon quantities in the field would be available.

*****

This requirement shall be considered acceptable by JPL when the PCASS can be mixed in an office using only the materials and equipment supplied with the PCASS kit.

(4) The PCASS shall be able to be prepared and loaded in the field during the training exercise to become the decontamination simulants for DS2 or supertropical bleach slurry.

*****

This requirement shall be considered acceptable by JPL when the PCASS can be mixed in an office using only the materials and equipment supplied with the PCASS kit.

(5) The cost of the PCASS shall be low enough that it does not preclude use in worldwide large (1000 soldiers) and small (10 soldiers) unit training.

Note: The potential use for the PCASS is greater than 100,000 gallons per year; an approved simulant, which will not meet these functional requirements, that now costs about $7.00 per gallon in the field is considered to be too expensive.

(6) The PCASS materials shall be field storable.

*****

This requirement shall be considered acceptable by JPL when the PCASS can be mixed in an office using only the materials and equipment supplied with the PCASS kit after being exposed to -45° and $+45^{\circ}C$ for 24 hours each.

(7) The PCASS materials shall be able to be used in existing Army decontamination equipments.

*****

This requirement shall be considered acceptable by JPL when the PCASS simulants can be used in an Army M11 decontamination spray device.

b. DESIRED

(1) The PCASS should not cause permanent damage or staining to clothing greater than the level normally experienced in field exercises.

(2) The PCASS materials should be procurable in large quantities.

Note: About 2000 gallons, when field mixed, could be used in a single battalion size training exercise.

(3) The PCASS materials should be commercially available.

(4) The PCASS individual materials should have a demonstrated shelf life of at least three years.

(5) The PCASS materials in concentrated or bulk form should not require special disposal requirements or processes.

(6) The PCASS materials in concentrated or bulk form should not be required to be classified as ammunition.

(7) PCASS materials should in the concentrated form, be liquids or granular or powdered solids.

APPENDIX 2
THE EFFECT OF AMBIENT CONDITIONS ON DROPLET DRYING TIME

For purposes of illustration of the variation of the drying time of the agent simulants with respect to varying ambient temperature and humidity conditions, we have assumed a hemispherical drop of 5mm diameter. Initial droplet temperature is assumed equal to ambient air temperature. While it is recognized that wind speed will affect these results significantly, we will assume for purposes of illustration a free convection (zero wind speed) condition.

The rate of evaporation is assumed to be proportional to the difference between saturated conditions near the droplet and the ambient conditions at distance.

$$\dot{m} = h(w_s - w_a) \qquad (1)$$

Where: $\dot{m}$ = vaporization rate; h = constant; w_s = spec. humidity at saturation; w_a = specific humidity at ambient conditions

The time to evaporate will be:

$$t = m / \dot{m} \qquad (2)$$

Where m = the total mass of the droplet

We can, therefore, compare the times of evaporation under different conditions by using equations (1) and (2).

$$\frac{t_2}{t_1} = \frac{\dot{m}_1}{\dot{m}_2} = \frac{w_{s_1} - w_{a_1}}{w_{s_2} - w_{a_2}} \qquad (3)$$

Using a standart psychrometric chart, the appropriate numbers can be obtained to compute the ratio of times for complete evaporation of the droplet.

The following table presents ratios of estimated drying time under varying conditions (representative of several average climates near military training areas) with respect to the acceptance criteria conditions of 80°F and 50% relative humidity.

Ambient Temperature	Relative Humidity	Estimated Ratio of Drying Time
80°F	50%	1.0
90°F	85%	2.4
100°F	90%	3.4
35°F	50%	5.8
50°F	80%	8.0

It is apparant from the calculated results that the conditions chosen for the OCASS acceptance are extreme for most areas of the country and most seasons of the year. It is recommended that the PCASS be modified in such a manner that varying formulations are available for use in diverse climates.

APPENDIX 3

MATERIAL SAFETY DATA SHEETS

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44-R1387

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MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME	EMERGENCY TELEPHONE NO.
Newage Industries Inc.	215-657-3151
ADDRESS (Number, Street, City, State, and ZIP Code) 2300 Maryland Road, Willow Grove, PA 19090	
CHEMICAL NAME AND SYNONYMS Compound mixture	TRADE NAME AND SYNONYMS Fernox C-11, D-33 & C-20
CHEMICAL FAMILY Boronitrites	FORMULA $Na_4B_4O_7$-NO_2 .H_2O

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS not applicable			BASE METAL		
CATALYST N.A.			ALLOYS		
VEHICLE None			METALLIC COATINGS		
SOLVENTS N.A.			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES N.A.			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)	has no boiling point	SPECIFIC GRAVITY (H_2O=1)	
VAPOR PRESSURE (mm Hg.)	none	PERCENT, VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)	none	EVAPORATION RATE (______ =1)	
SOLUBILITY IN WATER	3.5% (cold)		
APPEARANCE AND ODOR	crystalline substance		

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Lel	Uel
Has no flash point			

EXTINGUISHING MEDIA
Does not support combustion

SPECIAL FIRE FIGHTING PROCEDURES
None

UNUSUAL FIRE AND EXPLOSION HAZARDS
None

(Continued on reverse side)

MATERIAL SAFETY DATA SHEET

EFFECTIVE DATE: October 1, 1982

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I. IDENTIFICATION

PRODUCT NAME:	POLYOX® Water Soluble Resin 301		
CHEMICAL NAME:	Poly(ethylene oxide)	CHEMICAL FAMILY:	Polyethers
FORMULA:	$+CH_2CH_2\text{-}O+_n$	MOLECULAR WEIGHT:	> One million
SYNONYMS:	P.E.O., Polyethylene glycol, poly(oxyethylene)		
DEPARTMENT OF TRANSPORTATION	HAZARD CLASSIFICATION	None	
	SHIPPING NAME	None	
CAS # 25322-68-3	CAS NAME	Poly(oxy-1,2-ethanediyl), α-hydro-ω-hydroxy-	

II. PHYSICAL DATA

MELTING POINT	65 ± 2 °C (149 ± 3.6 °F)
DENSITY	1.21 ± 0.03 g/cm³ (1210 ± 30 kg/m³) at 25 °C
PER CENT VOLATILES BY VOLUME	Less than 1.0% by wt.
APPEARANCE AND ODOR	White powder; ammoniacal odor.

III. INGREDIENTS

MATERIAL	%	TLV (Units)	HAZARD
Polyethylene Oxide	97+	Not established	None currently known
Amorphous Silicon dioxide	< 2.0	6 mg/m³ Total Dust	
		3 mg/m³ Respirable Dust	
Calcium Oxide	< 1.0	2 mg/m³	

IV. FIRE AND EXPLOSION HAZARD DATA

AUTOIGNITION TEMPERATURE	536 °F, ASTM D 1929
EXTINGUISHING MEDIA	Use water spray (fog), carbon dioxide, dry chemical, regular, alcohol, or universal-type foams applied by manufacturer's recommended techniques.
SPECIAL FIRE FIGHTING PROCEDURES	Do not use a solid stream of water, it may scatter molten material and spread a fire. Use self-contained breathing apparatus, and protective clothing.
UNUSUAL FIRE AND EXPLOSION HAZARDS	Avoid dispersion of dust in air to reduce potential explosion hazard.

EMERGENCY PHONE NUMBER

304/744-3487

This number is available days, nights, weekends, and holidays.

UNION CARBIDE CORPORATION • SPECIALTY CHEMICALS AND PLASTICS DIVISION
OLD RIDGEBURY ROAD, DANBURY CT 06817

SECTION V - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

EFFECTS OF OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES
If swallowed, the patient would require oxygen to counteract the oxygen scavenging properties.

SECTION VI - REACTIVITY DATA

STABILITY			CONDITIONS TO AVOID
	UNSTABLE		N.A.
	STABLE		N.A.

INCOMPATABILITY *(Materials to avoid)*
All acids but can be utilized to neutralize acidic residues and to render

HAZARDOUS DECOMPOSITION PRODUCTS
solution neutral or slightly alkaline without risk

HAZARDOUS POLYMERIZATION			CONDITIONS TO AVOID
	MAY OCCUR		N. A.
	WILL NOT OCCUR		N. A.

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
sweep or wipe with water

WASTE DISPOSAL METHOD
Solutions acceptable in most sewage systems except where sewage is used in citrus fruit orchards

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION *(Specify type)*

VENTILATION	LOCAL EXHAUST	SPECIAL
	Crystals and solutions in water do not produce vapors	
	MECHANICAL *(General)*	OTHER

PROTECTIVE GLOVES
Not essential

EYE PROTECTION
Not essential

OTHER PROTECTIVE EQUIPMENT
Not essential

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING
Store away from strong acids

OTHER PRECAUTIONS

GPO 934-110

Form OSHA-20
Rev. May 72

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V. HEALTH HAZARD DATA

TLV AND SOURCE: None established by ACGIH or OSHA.

ACUTE EFFECTS OF OVEREXPOSURE

SWALLOWING	None currently known. May cause some nausea.
SKIN ABSORPTION	None currently known.
INHALATION	None currently known.
SKIN CONTACT	None currently known.
EYE CONTACT	None currently known.
CHRONIC EFFECTS OF OVEREXPOSURE	None currently known.
OTHER HEALTH HAZARDS	This product may contribute to nuisance dusts and possibly respirable dusts. Avoid breathing dusts.

EMERGENCY AND FIRST AID PROCEDURES:

SWALLOWING	No harmful effects expected.
SKIN	Wash with soap and water.
INHALATION	No emergency care anticipated.
EYES	Flush with water.

NOTES TO PHYSICIAN

Toxicology studies have shown the material to be of very low acute toxicity and nonirritant. There is no specific antidote. Treatment of overexposure should be directed at the control of symptoms and the clinical condition.

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VI. REACTIVITY DATA

STABILITY		CONDITIONS TO AVOID	
UNSTABLE	STABLE		
--	√		None

INCOMPATIBILITY (materials to avoid)	None
HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS	Combustion may lead to formation of carbon monoxide and/or carbon dioxide.

HAZARDOUS POLYMERIZATION		CONDITIONS TO AVOID	
May Occur	Will not Occur		
--	√		None

VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED	Collect for disposal. For cleanup, see Section IX.
WASTE DISPOSAL METHOD	Bury in a landfill where permitted under appropriate Federal, State, and local regulations.

VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (specify type)	Dust respirator in dusty conditions.		
VENTILATION	Special, local ventilation is recommended in areas where containers are opened and discharged, to minimize dusting.		
PROTECTIVE GLOVES	Plastic	EYE PROTECTION	Safety glasses
OTHER PROTECTIVE EQUIPMENT	Eye bath and/or safety shower		

IX. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Avoid breathing dust.
Avoid spills.
Use sweeping compound for cleanup, not water.

FOR INDUSTRY USE ONLY

OTHER PRECAUTIONS

Spilled POLYOX® should be removed promptly; floors can become slippery, especially when wet. In case of spills, use sweeping compound for cleanup. Apply laundry bleach to spill area. Allow to stand ten minutes and flush thoroughly with water. Repeat if necessary.

APPENDIX 4

ESTIMATES OF PRODUCTION COSTS

The following cost estimates are based on end-use quantities in 55 gallon increments. Due to the relatively small amount of material required for addition to 55 gallons of water to constitute agent simulants, the cost differential between a single 55 gallon unit lot and 100 units of 55 gallons each is quite small (2%) for the these simulants. The comparitive savings for the Supertropical Bleach Simulant are about 33% ($.20 against $.12) when going to 100 units of 55 gallons each.

The costs presented here are based only on the cost of material from quotes obtained from Myriad Industries, Chemical Division and Atlas Chemical Company. They are indicative of prices in affect at the time of writing and do not include the cost of labor, containers, labelling, or perfluorocarbon tracer material. The additional costs to which these items contribute will be discussed at the end of this Appendix.

SIMULANT	COMPONENT	COST/GALLON
BLISTER	Citric Acid	.18
	Polyox	.08
	Sodium Alginate	.24
	PEG 200	1.35
	Garlic Extract	.20
	FD&C Yellow	.02
	Total per gallon	2.12
NERVE	Sodium Carbonate	.03
	FERNOX	.03
	POLYOX	.19
	Sodium Alginate	.20
	PEG 300/400	1.40
	Total per gallon	1.88
STB	Calcium Carbonate	.01
	Spray Milk Pwd.	.20
	Total per gallon	.21

Tracer Technologies believes that the cost of manufacturing and the cost of containers would add approximately $2.00 per gallon the cost in single lot 55 gallon quantities.

In view of the current art in compact and portable instrumentation for measurement of the perfluorocarbon tracer and the economics of small quantity purchase, addition of tracer would raise the cost of the agent simulants by approximately

$3.00 per gallon. Pending developments in instrumentation and the increased bulk production of new perfluorocarbons for use as physiological oxygen carriers should reduce this additional cost by a factor of 100.

An extremely important factor in the total cost analysis is the cost of polyethylene glycol. Tracer Technologies believes that the amount of PEG in the PCASS be significantly reduced to allow 8 hour evaporation under environmental conditions which are more likely to be encountered than those specified as acceptance criteria in this contract. We believe that such a reduction in the amount of polyethylene glycol would cause the cost for the nerve and blister agent simulants to decrease to under $1.00 per gallon for the majority of training locations.

APPENDIX 5

MODEL HD-2P HALOCARBON MONITOR

THEORY AND OPERATION

The Tracer Technologies Model HD-2P Halocarbon Monitor is a portable instrument capable of measuring halocarbons in the parts-per-million concentration range. Its operation is simple and straightforward.

THEORY OF OPERATION

The monitor is based on the electron capture detector which exhibits a high sensitivity to highly electron absorbing compounds such as the perfluorocarbons and halocarbons in general.

The instrument operates in a continuous sampling mode rather than in a discrete sample mode as would a gas chromatograph. A flow of nitrogen is continuously applied to the detector. A source of ionizing radiation (300 mCi tritium source) in the detector produces thermal electrons and the resultant quiescent current is processed, amplified, and fed to a display. Electrophilic substances introduced into the nitrogen flow decrease the population of electrons and the resultant change in current is indicative of the concentration of electrophilic molecules in the detection chamber.

Directly sampling ambient air would introduce a high concentration of oxygen (to which the instrument also responds) and saturate the detector. To obviate this, some means of sample enrichment and oxygen elimination must be employed.

Several methods are available for accomplishing the removal of oxygen. In the HD-2P, the nitrogen carrier gas is separated from the sampled ambient air by a silicon elastomeric membrane. This membrane more readily diffuses halocarbons than oxygen. The result is an enrichment of the sampled air and a significant decrease in the amount of oxygen entering the carrier stream. Although some oxygen does cross the membrane and desinsitize the instrument to a greater degree than in instrument specificaly designed for detection of perfluorocarbons, the simplicity and portability of the halocarbon detector were the major factors in choosing its use in this study.

SETUP AND POWER UP

The HD-2P requires a source of nitrogen gas. This gas should be prepurified grade or better. Connection is made to the rear of the unit using 1/8 inch tubing and Swagelok connector. Delivery pressure should be set to 5 psig.

After nitrogen flow has been established, allow the instrument to purge for 30 minutes if maintinence flow has not been maintained. While the instrument is purging, attach the sampling probe to the rear panel inlet fitting marked INLET. Connect the meter to the BNC fitting marked METER. DO NOT use the connector marked OUTPUT.

After the instrument is purged, turn COARSE and FINE ZERO controls fully counterclockwise. Place the MODE switch in the ON position and adjust the ZERO controls for on-scale meter reading.

The instrument is now ready for use.

OPERATION

Operation is quite simple. Once running, it is only necessary to place the sample probe over the material to be tested. The instrument will respond in approximately 5 seconds.

Should the probe become contaminated, simply wash it off with water or isopropanol. CAUTION: DO NOT ALLOW LIQUID MATERIAL TO ENTER THE INSTRUMENT INLET.

This instrument responds to halocarbons in general and it is possible that some interferences may be seen on occasion. If interference is suspected, move the instrument to a cleaner environment or sample outside or purified air as a check on performance. The instrument will still operate with a minor contaminating background but its useful sensitivity will be reduced.

BATTERY CHARGING

The internal batteries are capable of powering the instrument for a minimum of 24 hours. It is, however, advisable to recharge the batteries after each 12 hours of use. To recharge, place the MODE switch in the OFF/CHG position and plug the charger cable into the CHARGE jack on the back panel.

STORAGE, CARE, AND MAINTINENCE

To minimize purge time when the instrument will be used periodically over several days, it is recommended that a purge flow be maintained when the instrument is not in use. Sufficient flow is maintained by backing the nitrogen regulator off until the delivery gauge is just off the zero pin.

Routine care is minimal and consists of keeping the batteries charged and preventing foreign material from entering the inlet probe.

MAINTINENCE

This instrument utilizes an electron capture detector which contains a 300 mCi titanium tritide foil source. Under no circumstances should this instrument be opened, modified, disassembled, or repaired except by TRACER TECHNOLOGIES. This restriction is a provision of the loan agreement set forth in this contract.

Should service or repair become necessary, contact TRACER TECHNOLOGIES at once at (619)480-8988.

APPENDIX 6

DISCUSSION OF INSTRUMENTATION TECHNOLOGY

The use of a taggent in the simulant provides an additional method by which to detect the presence of the simulant. This opens the possibility of using equipment that simulates the current and future technology in agent sensors and integrating this into the training system. Tracer Technologies believes that one of the most useful taggents that could be used are the perfluorochemicals. The materials are highly detectable using electron capture detectors and yet they are not so industrially prevelent that large backgrounds exist. The background level for these materials is well below a part per trillion (1 part in 10^{12}). The purpose of this section is to evaluate the levels of perfluorochemical required for tagging of the simulant and the instrumentation required to measure that taggent.

Two types of instruments have been developed and are currently used by Tracer Technologies. The first is a continuous perfluorochemical analizer that will only respond to the perfluorochemicals. Other halocarbon compounds to which the electron capture detector responds are eliminated by the use of a catalytic reactor. This instrument is portable but requires significant power and also requires a supply of nitrogen and hydrogen. It is capable of measuring concentrations in the rage of 10 to 1000 parts per trillion.

The second instrument uses a semi-permeable membrane and allows only small amounts of the sampled air to be introduced to a nitrogen stream. This instrument is the prototype instrument delivered to JPL for use in evaluating the PCASS. This instrument responds in the concentration range from 0.1 to 100 parts per million. The instrument is lightweight and can be used in a field situation. Further development could reduce the instrument size to approximately 50% of its current volume.

Given this description of the current technology, it is possible to evaluate the requirements for an ideal instrument for the purposes of measuring the taggent material. If we assume that we are considering a 5 mm drop that has a hemispherical shape and has the density of water then the drop will weigh 0.327 grams. We also will assume that the drop lasts 8 hours and that the vaporization rate of the drop is a constant 6.8E-5 g/min. If we now load the simulant with a perfluorochemical at 1% by weight and the vaporization rate of the perfluorochemical is the same as the drop, then a perfluorochemical vaporization rate of 6.8E-7 g/min results. The instrument samples at the rate of 30 ml per minute and assuming that all of the vaporization is contained in a 30 ml sample of pure air will result in a concentration of 1.8E-6 moles of taggent per mole of sample. Thus the instrument

will see approximately 2 parts per million. Similarly, if the loading is reduced to 0.1% then the instrument would see approximately 0.2 ppm.

The background level of potential interfering halocarbons is approximately 1.0E-10. Therefore if we operate in the range of 1.0E-9 (1 PPB) to 1.0E-6 (1 PPM) we will be above the background and yet within the range of reasonable amounts of taggent in the simulant material. Instrumentation currently exists that will detect the perfluorochemicals in concentrations well below the desired range, it is reasonable to expect that an instrument could be developed that would work in the desireable range and yet would be sufficiently portable to satisfy the training requirements.

Several questions arise about the overall concept of using a perfluorochemical taggent and should be answered. The current instrument requires the utilization of a nitrogen gas supply. Is it possible to develop an instrument without utilization of the nitrogen purge? In concept it is possible to develop a catalytic oxygen removal system that could provide the nitrogen supply without having a cylinder. Tracer Technologies believes that an instrument 30% of the size of the prototype instrument could be developed. The second area of interest is in the possibility of tagging different simulants with different taggents and then being able to detect which simulated agent is being used. This would require the development of a technique for seperating the taggents being utilized. It appears to us that there are two possibilities for doing this. One is that the new lighweight army agent detector which uses the ion mobility detector could be modified to respond the the taggents. This is technically feasible and could result in training utilizing the same instrument that is utilized in the real situation. The second possibility is that the Army is developing ultra-small chromatographic systems that might be utilized for detection of the perfluorocarbons.

The conduct of this study which developed a low cost water based simulant for use in troop training has convinced us that a perfluorochemical tracer is a feasible taggent for use with any simulant material. A significant amount of development work on instrumentation and testing would be required to make the system into a routine field training system, but the positive advantages of having a taggent system can make this a positive method to improve the training system.